Techniques to Assimilate SSM/I Observations of Marine Atmospheric Storms

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LONG-TERM GOALS

Our long-term goal is to use DMSP SSM/I satellite data to improve the depiction of marine atmospheric storms, which in turn would aid nowcasting in support of execution of operations at sea and forecasting of the evolution of these storms in support of planning. The anticipated results of our research are algorithms and prototype software to use SSM/I observations of integrated water vapor (IWV) and surface wind speed in data assimilation. These algorithms, based on the work of Hoffman and Grassotti (1996, referred to as HG96 below), are designed to match observable features in the SSM/I data to those in the short term forecast (or background) field used in the data assimilation system, shifting the background field to best match the available satellite data. The algorithms will be optimized for the Navy weather central regional prediction facility models but will be adaptable to other satellite data and other forecast models.

OBJECTIVES

In practical terms, the goal of this project is to translate the work of HG96 into an operational algorithm and to perform sufficient testing to demonstrate the utility of this algorithm by showing that it improves the forecasts of marine storms. To reach this goal we worked towards the following key technical objectives: case selection; impact study; algorithm development and tuning. Suitable cases for study were selected. For each selected case one or more impact experiments was conducted. These experiments showed the utility of applying the distortion correction within the operational data assimilation cycle, and provided quantitative measures of the improvements in forecast skill in the selected cases. The algorithm will be extended to allow for operational implementation. Tuning of the algorithm was refined.

APPROACH

In HG96 the method for shifting the background field is formally defined in terms of a distortion field, consisting of a field of horizontal displacements and amplification factors that are applied to the background. The distortion field is required to be large-scale and smoothly varying, and represented in terms of a spectral expansion in sines and cosines defined over the domain of interest. The distortion is determined by minimizing an objective function which constrains the distorted background field to closely fit the SSM/I data, and ensures that the final distortion produced by the minimization is

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relatively smooth and not too large. In HG96, the method was applied to SSM/I observation of IWV and large-scale analyses which did not use these data. In the present project, we adapt this method to adjusting the first guess field of the COAMPS data assimilation cycle. Short-term COAMPS forecasts used as the background field in the COAMPS analysis are distorted for a better fit with the SSM/I data over the ocean, and subsequently used in the COAMPS analysis.

WORK COMPLETED

Work during the past year has concentrated on several aspects: Case Study Selection, Impact Study, and Algorithm Development. To select appropriate cases for study, we obtained and examined daily operational Navy analyses and forecasts over the West Coast, along with imagery of SSM/I IWV retrievals. Our primary area of interest was a COAMPS domain over the West Coast of the United States. We identified several cases with clearly visible signatures in the IWV data, and interesting synoptic situations representing significant forecast challenges. Of those, three were studied in detail.

RESULTS

Two of the three case studies (19 March 1997 and 13-14 February 1998) involved corrections to the placement of a moist tongue and associated cold front of a mature oceanic storm.

The first case was used for a number of sensitivity studies. A 12-hour COAMPS forecast valid at 12 UTC 19 March 1997 was used as the first guess field in this case. The SSM/I data, which covers part of the moist tongue evident in the first guess IWV, indicates that the moisture tongue is too far to the west in the first guess. The adjustment algorithm was applied to this data using either displacements alone, or amplifications and displacements. In this case, however, the amplification had only a small effect (results are not appreciably different if only displacements are allowed for the adjustment). Adjustments are generally small in areas not covered by SSM/I data.

Two sets of control and adjusted forecasts were generated from the initial data at 12 UTC 19 March. In the nominal case, the first guess is further modified in the analysis step, which diminishes the differences between the control and adjusted initial state. Differences between the control and adjusted runs decrease further during the ensuing forecast. After 12 hours there are still some differences in the IWV fields, but they are much smaller than those of the first guess, both because of the analysis step and the evolution during the forecast. The position of the wind-shift line is no longer visibly different in the two forecasts. The forecasts of the "nodata" runs are initialized from the control and adjusted first guess fields (omitting the data analysis step). Results show somewhat larger differences between control and adjusted than in the nominal case.

Verification of the 12-hour IWV forecasts against SSM/I observations available at that time show that the adjustments have a small, but positive impact in terms of mean square statistics, although there is a concomitant increase in the positive bias. The improvement is greater for the nodata runs than for the nominal runs.

Verification of the 1-hourly precipitation totals against SSM/I observations of instantaneous precipitation show no clear positive or negative impact of the adjustments.

In the second case, the differences between the control and adjusted first guess (00 UTC 14 February 1998) are significantly modified by the analysis step: moisture values are reduced in both runs, leading

to much smaller differences in magnitude, although the position of the moist tongue is still further south in the adjusted run. After 12 hours into the forecast, however, the position of the moist tongue is no longer different, but there are slight differences in magnitude.

Verification of the 12-hour forecast IWV fields against SSM/I observations again show a small, but positive impact. Verification results for precipitation rates are neutral or slightly negative.

The first guess in the final case (12 UTC 15 January 1998) included a wave-like disturbance of the main moisture tongue, associated with a surface low pressure system. The adjustments based on the available SSM/I IWV data lead to a reduction of IWV values near the center of the low, and a general southeastward displacement of the features in the forecast field. However, the vorticity maximum associated with the low is also weakened by the adjustments. After the analysis step, the IWV fields are reduced in the control run, but increased in some areas in the adjusted run, leading to a reversal of the differences near the center of the low, and generally only small differences in the position of moist tongue. After 12 hours, there are few visible differences between the two runs, except for an area of slightly higher values in the adjusted run.

The results indicate that the adjustments to the first guess lead to an improvement of the IWV forecasts. They also indicate that the adjustments only partially survive the data analysis steps of the COAMPS data assimilation system, greatly diminishing its potential impact. Further study is also warranted into more effective ways of initializing the COAMPS model with the adjusted model fields, since the impact is further diminished during the first 12 hours of the forecast.

IMPACT/APPLICATIONS

The results obtained so far confirm the feasibility of our approach, and indicate the need to further study parts of its implementation. They do not yet have a direct impact on Navy operations.

TRANSITIONS

Our strategy for technology transition has both short-term and longer-term aspects. In the short term we expect that the method can be adapted to correct shipboard applications, in which short-term COAMPS forecasts can be corrected using locally available data such as SSM/I, radar, or other remotely sensed or in situ data. In addition for the Navy there are potential applications for TESS and NOGAPS.

Our medium term goal is to develop other applications of our method. We would first generalize the method to use all available observations to define the distortion. This will best be done in the context of 3- and 4-dimensional variational data assimilation, currently being developed at various centers. Further generalizations of the method potentially make it suitable for a range of other applications, ranging from the fusion of radar and satellite images of precipitation, to medical imaging, to machine vision.

RELATED PROJECTS

There are a number of AER projects closely related to this project. In a study sponsored by NASA we are evaluating the distortion methodology to characterize the properties of model forecast error from the Goddard EOS global model. AER is also a member of the NASA Scatterometer Science Team. AER's primary goal is to investigate the application of scatterometer data in numerical weather prediction models. We are focusing on algorithm development for scatterometer data retrieval, ambiguity removal, fusion with other sensors, and assimilation by numerical weather prediction models. In another project sponsored by NASA we aim to optimize the use of scatterometer data for NWP purposes by combining the SeaWinds scatterometer data with data from other microwave sensors. There is a close relationship between these projects and the current work since the scatterometer, like the SSM/I, has the potential of detecting oceanic storms. In addition, we have conducted several projects investigating the use of optimum interpolation for global and mesoscale data assimilation, and the use of satellite data in data assimilation.

REFERENCES

Descriptions of this and other projects can be found on AER's home page: http://www.aer.com, by selecting "Groups", "Numerical Weather Prediction", and "Major Projects" (http://www.aer.com/groups/nwp/m-proj.html).

R. N. Hoffman and C. Grassotti, 1996: A technique for assimilating SSM/I observations of marine atmospheric storms. J. Applied Meteorol., 35, 1177-1188.

IN-HOUSE/OUT-OF-HOUSE RATIOS

One hundred percent (100 %) of the work was performed in-house.